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THE ANALOG IMAGE PROCESSING COMPONENT OF THE CIRCLE GRAPHICS HABITAT

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Background

For a number of years I worked in still color photography utilizing many optical and chemical processing techniques to modify images. In attempting to transfer these techniques to moving images (film), the same processes which had been successful in still photography proved to be much too slow and cumbersome in film. The rather free experimentation and play that I needed to find and refine ideas became impossible. The process became so slow that I couldn't find out what it was I needed to know to figure out what it was I wanted to do.

The idea of an instantaneous electronic image processor appeared to be possible which would allow even more freedom and power with moving images than was possible in still photography by chemical and optical techniques.

The General Structure of the Image Processor

Although the image processor can process any electronic signal within its bandwidth (DC to 4 MHz), it is optimized for processing images in the American standard television format. At any given instant in time the video signal coming from a video device represents the brightness of a particular point on the television screen. The brightness is encoded in terms of a continuum of voltages, representing a continuum of gray levels. This identity of voltages and gray levels make possible the simple point by point processing of the TV images by real time processing of the voltages representing the gray levels of the image. Thus for a large class of transformations the image need not be stored. This is

very important, because storing a single frame of video requires 250,000 8-bit words of storage and frames happen 30 times a second.

The Image Processor (IP) is a collection of analog processing modules (figure 1) performing simple or primitive processes (calculations) on the video signal which results in a processing of the gray levels making up the image. The system is programmed by routing signals from the input, through processing modules to the output of the instrument. Description of the individual modules follows.

TV Input Module

This module takes a black and white video signal as input, removes the synchronization information and outputs only the gray level information with black being represented as -.5 volts and white being represented as +.5 volts. A color input module which will output red, green, and blue monochrome signals, is presently being designed. The classic Image Processor has three of these modules.

Output Module (Color Encoder)

This module has three inputs (red, green, blue) which accept monochrome signals from the IP. The modules outputs a standard N.T.S.C. color signal (American standard). The red input can be thought of as controlling the red gun in a TV monitor connected to the IP. The green and blue inputs function similarly. In combination with sync generators and externally synchronizable sync generators this module handles all the technical amenities of the television signal.

Comparitor

The comparitor compares two input signals. When the "top" input is at a higher voltage (whiter) than the "bottom" input the module outputs +.5 volts

(white); when the "top" input is at a lower voltage (darker gray level) than the "bottom" input, the module outputs -.5 volts (black). The net result is that all areas of an image put into the top input that are lighter than the gray level at the bottom input are made white. All areas of the image that are darker than the gray level at the bottom input are made black. This is similar in effect to high contrast film (Kodalith) except that the transition gray level can be varied easily (with a knob), or can be a time varying signal or even an image. Figure 3 shows the effect of the comparitor on a source image (figure 2). This image (Figure 2) is put in to the top input and the bottom input is at middle gray, 0 volts. The classic Image Processor contains three comparitors.

Differentiator

The differentiator takes the derivative of voltage with respect to time. In the TV format this is equivalent to taking the spatial derivative from left to right of gray level. The net result is to suppress areas of the picture which are of the same gray level and to emphasize edges and textures (see figure 4). The classic Image Processor contains three differentiators.

Diode Function Generator

The function generator creates an input-output transfer function based on three continuous line segments. Consider a graph of input to output (figure 5). Curve a represents a linear transfer which results in no change of the image; curve b and c represent two other transfer curves. The corresponding visual results are shown in figures 6 and 7. Three knobs control the slope of the transfer curve in the black to dark gray region, middle gray region, and light gray to white region respectively. The visual effects are similar to solarization in photography but more controllable. There are three functions generators in the classic Image Processor.

Amplitude Classifier

This module divides an incoming signal into eight equally spaced gray level regions from black to white. In each of these gray level regions the module outputs a gray level proportional to knob position and controls voltage. Two of the possible transfer curves are showm in figures 8 and 9 with corresponding visual effects shown in figures 10 and 11. The output of each region is available individually and is available summed together. The pictures are of the summed output. The classic Image Processor contains three of these modules.

Adder Multiplier

The adder multiplier consists of three sets of inputs. Set A, called the black channel (from the color of its gain control knobs), consists of four inputs, three of which are added together and a fourth which is subtracted. Set B, called the silver channel, likewise consists of four inputs, three of which are added and a fourth which is subtracted. Channels A and B are added together in proportion to a knob position and control voltage put into the multiply input. If the multiply input is white, channel B (silver) is put out with gain 1 and channel A (black) is turned off. If middle gray (0 volts) is put into the multiply input, channels A and B are added together, each with gain ½. If black (-.5 volts) is put into the multiply input, channel A (black) is put out with gain 1 and channel B (silver) is shut off. The control is continuous and linear. The visual effect of addition is superimposition. Figure 12 shows the addition of images shown in figure 1 and figure 13. Multiplication of two images is somewhat more unique. Figure 14 shows the image of the sunset (figure 2) multiplied by an image of the author (figure 13). Figure 15 is the same but the gain control over the image of the author (me) has been increased so that most of the time channel A or B is either full on or full off. The classic Image Processor contains

eight of these modules.

Oscillator

The oscillator is a signal source which generates time varying signals sinusoidal, triangle, and sawtooth of frequencies from .01 Hz to 1 MHz. The frequency is controllable by both knob position and control voltage. At low frequencies (less than 30 Hz) the modules are used to control other processes such a a recurring fade between two images or flashing a particular region of an amplitude classified image. At higher frequencies the oscillators generate patterns. If the frequencies are multiples of the horizontal or vertical scan frequencies the patterns are stable. (See figure 16.) To make stable patterns easier to find and more stable, the oscillators are triggerable, usually by the scan synchronization signals. The classic Image Processor contains six oscillators.

Quasi Static Voltage Sources

In and around the Image Processor there are many voltage sources where the outputed voltage is proportional to position of a knob or other device. One module, called the reference, contains nine voltage sources proportional to knob position. Also, there are two and three dimensional joy sticks, slide potentiometers, and other devices that are physically separate from the IP for ease of the user. These voltage sources are used (in addition to the knobs associated with each module) to control the Image Processor. For example, they can be used to set the transition gray level on a comparitor, to dissolve from one set of images to another set of images, or to control an oscillator that is controlling something else, etc. Soon I hope to develop several multi-dimensional controls other than position to enhance the variety of control. Three dimensional pressure sensors, sound sensors, biological and environmental

sensors are high on the list of proposed voltage sources.

Simple Combinations of Modules

By routing images (video signals) from the input through several modules to the output, processes can be synthesized which are entirely different than the individual primitive processes. For example, if the image of the sunset is routed to the comparitor and then to the differentiator, the result (figure 17) is different than the result of using the comparitor alone (figure 3) or of using the differentiator alone (figure 4). A common television special effect is a key. For example, inserting news pictures apparently behind the news announcer. If the image of the sunset is put into the comparitor and the output of the comparitor (figure 3) is put into the multiply input of an adder multiplier, and the sunset (figure 2) is put into channel A (black) of the adder multiplier, and an image of me (figure 13) sent to channel B (silver), the resulting image is figure 18. Notice that the image of me has been inserted into the lighter areas of the sunset. Figures 19, 20, and 21 show other processes described in the captions.

Color in this instrument is handled as three monochrome signals--- red, green, and blue signals. If identical signals are put into red, green, and blue inputs of the color encoder (output module) a black and white image results. If different signals are sent to the red, green and blue inputs of the output module, a colored image results. Any hue saturation and gray level that can be displayed on an American standard color TV set can be produced by combinations of these three signals. For example, if an image were sent to three amplitude classifiers and the output of each were sent to the red, green and blue inputs of the output module, each of the eight regions of the output image (similar to figure 10 or 11) could be adjusted to any color and gray value wished. An example of this cannot be shown because color reproduction is not possible in this journal.

The Formal Power of the IP

The term "formal power" is used here to refer to the large number and variety of processes possible with the instrument. The Image Processor is of course not as formally powerful as non-real time image processing systems based on general purpose digital computers just as digital computers are less powerful in this sense than a Turing machine. The IP is, however, much more formally powerful than its closest neighbors, the special effects generator in a commercial TV studio, and most video synthesizers in use today. This difference in power comes from a small number of differences in structure. First, knobs, control voltages, and images are interchangeable. This enables the periodic and remote control of many functions and the control of the processing of one image by another image. This gives rise to huge combinational possibilities. Second, the primitive processes are more basic than complete effects and are embedded in a context that allows combinations of processes to produce effects that were never forseen by the designer. These structural features plus a liberal number (35) of processing modules give rise to an analog machine of considerable generality.

The Real Power of the Image Processor

The term "real power" is used here to denote what people (users) can do with a system as compared with formal power which refers to what the machine can do. The Image Processor was designed for use by art students and artists to generate and explore complex, colorful, kinetic images. People of a huge range of differing training and working styles have been able to use the Image Processor successfully without too much culture shock. Some of the structural aspects that contribute to the Image Processor's real power are, first, the high tactility and physicality of the IP. The instrument is controlled by turning knobs, sliding sliders, and joying joysticks. Programs are created by

connecting cables. Signals are routed from one place to another by connecting cables from one place to another. Therefore, one can hold a cable in one hand and think, this is the image of the sunset--let's put it into the function generator! More importantly, one does not even have to think "put it into the function generator." It is very hard to describe visual phenomena linguistically. This is part of the power of imagery. Images can deal with things that are hard to talk about. Another pbysical aspect of the machine that makes it easier to use is that things that look alike do alike. All gain controls have one type of knob, all biases another type of knob, and all time related controls yet another type of knob. All outputs of modules are in particular redundant arrangements on the right hand side of the modules. If two modules look identical, they are identical in function. Another important user oriented feature is that a non-malicious user cannot hurt the machine. This lowers fear and enables rather free experimentation with no negative consequences. The most important aspect enhancing the real power of the IP is the rich and instant feedback. The limit of doing and learning is set by physical limitations and thinking limitation, not by delay or error in the feedback loop.

The Image Processor's Function in the Digital Environment

By pointing television cameras attached to the IP at a monochrome vector drawing system, one can colorize the bright line drawing images. If more than one camera is used on separated images on the display screen, simple color coding is possible. The colors (which cannot be shown here) can be any that color TV can display. It is also easy to generate background colors or colored patterns around the lines of the vector display. Further, the Image Processor can combine real time live images with the computer generated images and handle both signals in a uniform way.

A powerful but disrelated use of the Image Processor is to preprocess

images for automatic digitization by the computer. Because the user can see the simplified image before digitization, he can use good human patter recognizing techniques to isolate relevant features of the image. (See figure 1.)

The Image Processor was originally designed to stand alone and be used as a personal, creative, and exploratory instrument. Indeed, most of the fifteen copies of this instrument are owned by individual video artists. Happily, the Image Processor's cohabitation with Tom DeFanti's vector drawing graphic system (GRASS) has proven to be a most successful synergy.